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DETERMINATION OF PHYSICAL CHARACTERISTICS OF SOIL IN PALVAN OF CHIPLUN TEHSIL

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ABSTRACT

Soil is a natural substance that provides useful support for plant growth and agricultural production. The synthesized profile of the soil substance makes some variable improvement for agricultural production over any geographical area. This paper presents the methodology adopted and the results obtained for determining the various physical characteristics of the soil like soil textural class, infiltration rate, hydraulic conductivity, bulk density, porosity, field capacity and permanent wilting point of the soil. It was found that the soil of experimental plot was sandy loam having basic infiltration rate 6.27 cm/hr and hydraulic conductivity 4.91 cm/hr. The bulk density of soil was observed as 1.40 g/cm^3 with the porosity of 47.04 per cent. Also, the field capacity of the soil was 26.81 per cent and permanent wilting point was 11.6 per cent.

KEYWORDS: Physical Characteristics, Textural Class, Infiltration Rate, Hydraulic Conductivity, Bulk Density, Porosity, Field Capacity & Permanent Wilting Point

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INTRODUCTION

Soil moisture content information is needed for studies across a variety of disciplines, such as hydrology, soil science, ecology, meteorology and agronomy. The accuracy of soil moisture estimates depend on the particular application and associated spatial scale of interest. For example, monitoring the spatial variability of soil moisture content with sub-meter resolution over time is important for effective agricultural irrigation, particularly in water-deprived regions with high value crops, such as premium wine grapes (Lunt *et al.* 2005).

The importance of the soil as a reservoir of nutrients and moisture for the production of forage and plant species has been recognized since the beginning of the forest management as a science (Schlesinger et al., 1990). Available mixture of broken and weathered minerals and decayed organic matter, which covers the earth in a thin layer and which supplies, when containing the amounts of air and water, mechanical support and imparts sustenance for plants (Brady and Weil, 2000). Partial heterogeneity in physical properties of soil affects not only the spatial patterning of vegetative cover but overall community structure and productivity (Brady and Weil, 1990).

MATERIALS AND METHODS

Soil Sampling Technique

Total four soil samples were collected from four different depths (15, 30, 45 and 60 cm) of the four

corners and center of the field using soil auger. All collected samples were mixed properly and a composite sample of 1 kg was used for determining physical properties of the soil. These soil samples were dried in oven at a temperature of 105 ^{0}C for 24 hours. The soil samples were passed through 2 mm size sieve and used for determining sand, silt and clay content using Bouyoucos hydrometer method (Bouyoucos, 1962).

Textural Classification of Soil

The textural classification was essential to know the distribution of particles in soil and to show the per cent distribution of soil textural class in the study area. The soil consists of particles of widely varying sizes. The distribution of these particles defines the soil texture. The soil texture classification was done by using Bouyoucos hydrometer method (Bouyoucos, 1962). The major classes by Indian Society of Soil Science (ISSS) system for sand, silt and clay are reported in Table 1.

Table 1: Particle Size Limits

Sr. No.	Soil Particle Size	Size Limits (Diameter in mm)
1	Clay	< 0.002
2	Silt	0.002 - 0.020
3	Sand	> 0.020

Bouyoucos Hydrometer Method

The Bouyoucos hydrometer method is based on Stoke's law and is used to determine the per cent sand, silt and clay of sampled soil.

Oven dried soil samples extracted from each depth weighing 40 g were passed through 2 mm sieve twice. The samples were transferred to a 600 ml beaker and 200 ml of distilled water was added. Then 4 to 5 ml of 30 per cent Hydrogen Peroxide (H_2O_2) was added. The beaker was covered with watch glass and placed it on water bath until most of organic matter was destroyed. The beaker was removed from water bath and allowed it to cool. The process was repeated until the colour of suspension ceased to become lighter or until frothing stopped. Total 15 ml of H_2O_2 was used for each 40 g sample. After the addition of H_2O_2, the beaker with soil was placed on the water bath for two hours to remove excess H_2O_2. While waiting for oxidation of organic matter, 10 ml of sodium hexametaphosphate solution was added in 1000 ml cylinder and filled the cylinder with distilled water to make exactly one litre. The suspension was mixed thoroughly and brought it to room temperature. Hydrometer was inserted into solution and observations were recorded on the scale reading. The reading was noted down as a calibration correction. The soil sample free from organic matter was transferred to the dispersing cup and filled it with distilled water up to the level of 4 cm from the top and 10 ml sodium hexametaphosphate solution was added. The soil was allowed to soak for 15 minutes. Then stirred the soil suspension in the cup with the help of high speed electric stirrer for 10 minutes. Then poured and washed the contents of dispersing cup into one litre cylinder with distilled water up to one litre mark. A rubber stopper was placed on the mouth of a cylinder and shake it mechanically for one minute. The cylinder was placed on the table and time was noted down immediately. First hydrometer reading was noted after 4 minutes when particle larger than 0.02 mm in diameter were settled. The temperature of suspension was also recorded. The hydrometer was calibrated at 19.44^{o}c (67 ^{0}F) and the correction was applied for the different temperatures. If working temperature is above 19.44^{o}c (67 ^{0}F) the correction was added, if below 19.44^{o}c (67 ^{0}F), the correction was subtracted. The correction was equal to the difference between working temperature and 19.44^{o}c (67 ^{0}F), multiplied by 0.2. The suspension was allowed to remain undisturbed and re-inserted the hydrometer at the end of two

hours after the initial shaking was stopped. The particles larger than 0.002 mm, i.e. sand + silt were settled. The hydrometer reading was noted down. Percentage of sand, silt and clay in soil sample were determined by using Equation 1.

$$P = \frac{\text{Hydrometer reading} - \text{calibration correction}}{\text{Soil weight (gm)}} \times 100 + \text{Temperature correction} \tag{1}$$

$$\text{Percent sand} = 100 - P_4$$

$$\text{Percent clay} = P_{120}$$

$$\text{Percent silt} = 100 - (\text{percent sand} + \text{percent clay})$$

Where,

P_4 = Per cent particle of soil settled at 4 min.

P_{120} = Per cent particle of soil settled at 120 min.

The textural classes for all samples were determined using TAL software in which the per cent sand, silt and clay were inputs and it shows texture class of soil using United States Department of Agriculture (USDA) soil textural triangle.

Infiltration Rate

Infiltration rate is defined as the volume flux of water flowing into the soil profile per unit of soil surface area (Hillel, 1980).

Representative location in the field was selected to determine the basic infiltration rate of the soil. The concentric double ring infiltrometer method was employed to determine the basic infiltration rate. Concentric double ring infiltrometer having diameter of inner ring and outer ring as 30 cm and 45 cm, respectively was used. Clearing the land surface and any vegetation that may hamper free movement of the water was removed without disturbing the soil structure. The inner ring with the cutting edge was placed facing down on the ground. Then the driving plate was placed on the top of the inner ring and the impact absorbing hammer was used to insert the infiltration ring about 10 cm vertically into the soil. After that, the outer ring was placed with the cutting edge facing down around the inner ring and inserted vertically into the soil by using the driving plate and the impact absorbing hammer. The measuring bridge with measuring rod and float was placed on the top of the inner ring. The outer ring was first filled with water, then the inner ring, to a depth of approximately 10-12 cm. The fall of water level was recorded after 5 min, 10 min, 20 min, and 30 min interval. The recording time was increased with an interval of 30 min. Recording was terminated after the rate of fall of water level was approximately constant. The measurements continued until the infiltration rate became steady. That rate considered as the basic infiltration rate of soil.

Hydraulic Conductivity

The hydraulic conductivity is defined as the volume of water that will move through a soil medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. Its unit of measurement is length per time (i.e. m/d). There are various methods to estimate hydraulic conductivity and the selection depends on the practical applicability. Inverse auger hole method is used when water table is comparatively deeper. It is one of the simplest methods to determine unsaturated hydraulic conductivity. Therefore it was used in present studies. The hole was augered in the soil to the 60 cm depth. The hole was filled with water, which was left to drain away freely. The hole refilled with water several times until the soil around the hole was saturated over a considerable distance and the

infiltration rate has attained a constant value. After the last refilling of the hole, the rate of drop of water level in the hole was measured with scale.

The hydraulic conductivity was determined by following formula applicable to inverse auger hole method.

$$K = 1.15r \frac{\log\left(h_0 + \frac{1}{2}r\right) - \log\left(h_t + \frac{1}{2}r\right)}{t - t_0} \quad (2)$$

Where,

t = time since the start of measuring (sec)

h_t = the height of the water column in the hole at time t (cm)

$h_0 = h_t$ at time t=0

The values of h_t are obtained from

$$ht = D' - H_t \quad (3)$$

Where,

D' = the depth of the hole below the reference level (cm)

H_t = the depth of the water level in the hole below reference level (cm)

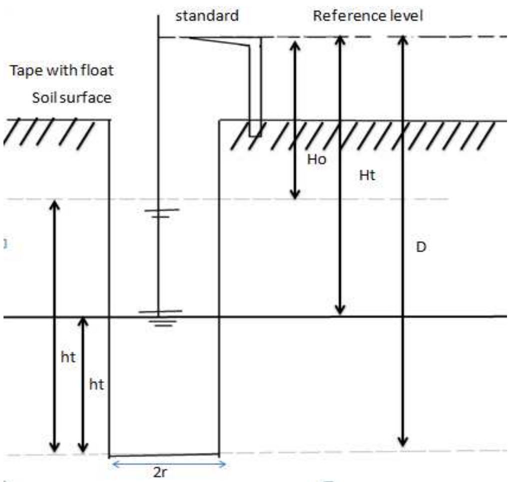

Figure 1: Hydraulic Conductivity by Inverse Auger Hole Method

Bulk Density

Soil bulk density is defined as mass per unit bulk volume of soil in undisturbed condition. A core sampler was used to take undisturbed soil samples. The cylinder of the core sampler, which has its cutting edge, was driven into the soil. The sample was carefully trimmed at both ends of core cylinders. They are dried in an oven at 105^0C to 110^0C for about 24 hours, until all the moisture is driven off and the sample was weighted again. The volume of soil core was the same as the inside volume of core cylinder. The weight of soil divided by the volume of soil core is the bulk density of soil. The bulk density was determined by using following formula.

$$\text{Bulkdensity}P_s = \frac{\text{Mass of soil core}}{\text{Volume of soil core}} \tag{3}$$

Porosity

Porosity can be defined as the ratio of the volume of pores (voids) to the total soil volume. Porosity is expressed mathematically as the ratio of soil particles. Porosity of soil was estimated from the measured values for bulk and particles density of soil. Particle density is mass per unit volume of soil solid particles and is expressed as the total mass of soil (solid) particles to their total volume excluding pore space volume. Porosity of soil was determined by using equation 4 (Dough B. *et al*. 2013).

Assuming a soil particle density was 2.65 g cm^{-3},

$$\text{Porosity (\%)} = \left(1 - \frac{P_b}{P_p}\right) \times 100 \tag{4}$$

Where,

P_b = Bulk density (g.cm^{-3})

P_p = Particle density (g.cm^{-3})

Field Capacity

The field capacity of soil is the moisture content after the drainage of gravitational water has become very slow and the moisture content has become relatively stable. This situation usually exists for one to three days after the soil has been thoroughly wetted by rain or irrigation. At the field capacity, large soil pores are filled with air and the micro pores are filled with water.

Field capacity was determined by ponding water on the soil surface in the area of 2 m^2 and permitting it to drain for one to three days. One to three days after the soil was thoroughly wetted, soil samples were collected with an auger from different soil depths at the uniform intervals throughout the wetted zone. The moisture content was determined by the gravimetric method.

Permanent Wilting Point

The permanent wilting point, also known as permanent wilting percentage or wilting co-efficient, is the soil moisture content at which plants can no longer obtain enough moisture to meet transpiration requirements; and remain wilted unless water is added to the soil. At the permanent wilting point the films of water around the soil particles are held so tightly that roots in contact with the soil cannot remove the water at a sufficiently rapid rate to prevent wilting of the plant leaves. The moisture tension of a soil at the permanent wilting point ranges from 7 to 32 atmospheres, depending on soil texture and condition of the plants, and amount of soluble salts in the soil solution, and to some extent on the climatic environment.

Permanent wilting point was determined by grow indicator plants in containers. Sunflower plants were used as the indicator plant. The plants were allowed to wilt and are then placed in a chamber with an approximately saturated atmosphere to test them for permanent wilting. The residual soil moisture content in the container is then calculated which is the permanent wilting percentage.

RESULTS AND DISCUSSIONS

Textural Classification of Soil

Observations

- Weight of oven dry soil = W = 40 g
- Hydrometer reading at 4 min (R_4) = 9.5
- Temperature at 4 min = 28°C = 82.4 °F
- Hydrometer reading at 120 min (R_{120}) = 3.0
- Calibration correction = R_L =0

Calculations

Temperature correction = [Working temperature - 67 °F] x 0.2

= [82.4-67] x 0.2

= 3.08

$$P_4 = \frac{R_4 - R_L}{W} \text{ x } 100 \pm r$$
$$= \frac{95 - 0}{40} \text{ x } 100 + 3.08$$
$$= 26.83$$

$$P_{120} = \frac{R_{120} - RL}{W} \text{ x } 100 \pm r$$
$$= \frac{3.0 - 0}{40} \text{ x } 100 + 3.08$$
$$= 10.58$$

% sand = 100-P_4

= 100 – 26.83

= 73.17%

% clay = P_{120}

= 15.2 %

% silt = P_4-120

= 26.83 – 15.2

=11.63%

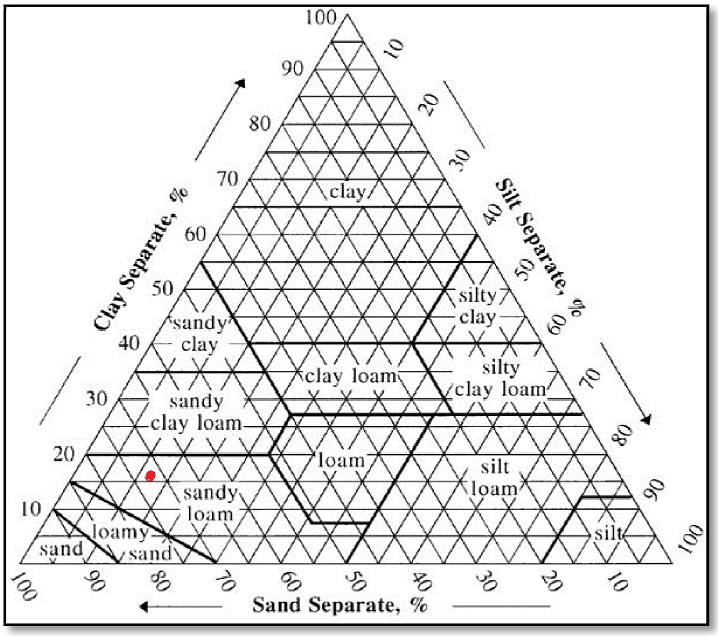

Figure 2: Textural Classification of the Soil

Thus, it was observed that per cent sand, silt and clay were 73.17%, 15.2% and 11.63% respectively. The textural class of the soil was sandy loam.

Bulk Density of the Soil

Observations

- Height of the core cutter = 13 cm
- Diameter of the core cutter = 10 cm
- Radius of the core cutter = 10 cm

$$\text{Volume of the core} = \pi\pi^2 h$$
$$= 3.14 * 5^2 * 13$$
$$= 1020.5\,\text{cm}^3$$

Table 2: Determination of the Bulk Density of the Soil

Replication	**Weight of Core Cutter (g)**	**Weight of Core Cutter + Wet Soil (g)**	**Weight of Core Cutter + Oven Dry Soil (g)**	**Weight of Soil Core (g) *(3) - (1)***	**Bulk density = $\frac{\text{Mass of soil core}}{\text{Volume of soil core}}$ (g/cm^3)**
1	952	2649	2324	1372	1.334
2	952	2740	2449	1497	1.460
3	952	2738	2400	1446	1.410
Average					1.40

Thus, it was observed that the average bulk density of the soil was 1.40 g/cm^3.

Porosity of Soil

Table 3: Porosity of the Soil

Replication	Bulk Density (g/cm^3)	Particle Density	Porosity = $\left(1 - \frac{\text{Bulk density}}{\text{Particle density}}\right) * 100$ (%)
1	1.34	2.65	49.43
2	1.46	2.65	44.90
3	1.41	2.65	46.79
Average			47.04

Thus, it was observed that porosity of the soil was 47.04%

Field Capacity

Table 4: Field Capacity of the Soil

Replication	I	II	III
Field capacity (%)	28.57	26.31	25.55
Average Field capacity (%)	26.81		

Thus, it was observed that the field capacity of the soil was 26.81 %

Basic Infiltration Rate of the Soil

Table 5: Basic Infiltration Rate of the Soil

Replication 1					Replication 2					Replication 3				
Elapsed Time (min)	Distance of Water Surfaces from Ref. Point: Before Filling (cm)	Distance of Water Surfaces from Ref. Point: After Filling (cm)	Infiltration During Period: Depth (cm)	Infiltration During Period: Average Infiltration ($cm.hr^{-1}$)	Elapsed Time (min)	Distance of Water Surfaces from Ref. Point: Before Filling (cm)	Distance of Water Surfaces from Ref. Point: After Filling (cm)	Infiltration During Period: Depth (cm)	Infiltration During Period: Average Infiltration ($cm.hr^{-1}$)	Elapsed Time (min)	Distance of Water Surfaces from Ref. Point: Before Filling (cm)	Distance of Water Surfaces from Ref. Point: After Filling (cm)	Infiltration During Period: Depth (cm)	Infiltration During Period: Average Infiltration ($cm.hr^{-1}$)
-	-	10	-	-	-	-	10	-	-	-	-	10	-	-
5	8.5	10	1.5	18	5	8.6	10	1.4	16.8	5	8.5	10	1.5	18
10	9.0	10	1.0	12	10	8.8	10	1.2	14.4	10	9.0	10	1.0	12
15	9.1	10	0.9	10.8	15	9.0	10	1.0	12	15	9.0	10	1.0	12
30	8.2	10	1.5	7.2	30	8.2	10	1.5	7.2	30	8.6	10	1.4	5.6
45	8.2	10	1.5	7.2	45	8.3	10	1.5	6.8	45	8.6	10	1.4	5.6
60	8.4	10	1.6	6.4	60	8.3	10	1.5	6.8	60	8.5	10	1.5	6
75	8.4	10	1.6	6.4	75	8.4	10	1.6	6.4	75	8.5	10	1.5	6
90	8.4	10	1.6	6.4	90	8.4	10	1.6	6.4	90	8.5	10	1.5	6
105	8.4	10	1.6	6.4	105	8.4	10	1.6	6.4	105	8.5	10	1.5	6
120	8.4	10	1.6	6.4	120	8.4	10	1.6	6.4	120	8.5	10	1.5	6
Basic Infiltration Rate ($cm.hr^{-1}$)														
6.4					6.4					6.0				
Average Infiltration Rate ($cm.hr^{-1}$)														
6.27														

Thus, it was observed that the basic infiltration rate of the soil was 6.27 cm/hr.

Hydraulic Conductivity of the Soil

Table 6: Hydraulic Conductivity of the Soil

Replication 1				**Replication 2**				**Replication 3**			
d = 6cm r = 3 cm				d = 6cm r = 3 cm				d = 6cm r = 3 cm			
D' = 38 cm				D' = 44 cm				D' = 48 cm			
t (sec)	**H_t (cm)**	**H_t=D'- H_t (cm)**	**$h+\frac{1}{2}r$ (cm)**	**t (sec)**	**H_t (cm)**	**H_t=D'- H_t (cm)**	**$h+\frac{1}{2}r$ (cm)**	**t (sec)**	**H_t (cm)**	**H_t=D'- H_t (cm)**	**$h+\frac{1}{2}r$ (cm)**
0	35.5	2.5	4.0	0	42.0	2.0	3.5	0	45.5	2.5	4.0
50	35.0	3.0	4.5	30	41.5	2.5	4.0	35	45.0	3.0	4.5
115	34.5	3.5	5.0	80	41.0	3.0	4.5	90	44.5	3.5	5.0
200	34.0	4.0	5.5	135	40.5	3.5	5.0	145	44.0	4.0	5.5
290	33.5	4.5	6.0	200	40.0	4.0	5.5	200	43.5	4.5	6.0
400	33.0	5.0	6.5	275	39.5	4.5	6.0	290	43.0	5.0	6.5
525	32.5	5.5	7.0	370	39.0	5.0	6.5	385	42.5	5.5	7.0
670	32.0	6.0	7.5	465	38.5	5.5	7.0	480	42.0	6.0	7.5
740	31.5	6.5	8.0	565	38.0	6.0	7.5	565	41.5	6.5	8.0
975	31.0	7.0	8.5	730	37.5	6.5	8.0	690	41.0	7.0	8.5
-	-	-	-	820	37.0	7.0	8.5	795	40.5	7.5	9.0
-	-	-	-	-	-	-	-	910	40.0	8.0	9.5
Hydraulic Conductivity (cm/hr)											
$K = 1.15 * r * \left[\frac{\log\left(h_0 + \frac{1}{2}r\right) - \log\left(h_t + \frac{1}{2}r\right)}{t - t_0}\right]$ $K = 1.15 * 3 * \left[\frac{\log(4.5) - \log(8)}{740 - 50}\right]$ $K = 1.249 * 10^{-3}$ cm/hr $K = 4.5$ cm/hr				$K = 1.15 * r * \left[\frac{\log\left(h_0 + \frac{1}{2}r\right) - \log\left(h_t + \frac{1}{2}r\right)}{t - t_0}\right]$ $K = 1.15 * 3 * \left[\frac{\log(4) - \log(8)}{730 - 30}\right]$ $K = 1.478 * 10^{-3}$ cm/hr $K = 5.32$ cm/hr				$K = 1.15 * r * \left[\frac{\log\left(h_0 + \frac{1}{2}r\right) - \log\left(h_t + \frac{1}{2}r\right)}{t - t_0}\right]$ $K = 1.15 * 3 * \left[\frac{\log(4.5) - \log(9)}{795 - 35}\right]$ $K = 1.36 * 10^{-3}$ cm/hr $K = 4.90$ cm/hr			
Average Hydraulic Conductivity ($cm.hr^{-1}$) = 4.90											

Thus, it was observed that the hydraulic conductivity of the soil was 4.90 cm/hr.

CONCLUSIONS

The physical characteristics of the soil such as textural class, field capacity, permanent wilting point, bulk density, porosity, basic infiltration rate and hydraulic conductivity were determined. The class of the soil of experimental plot was found to be sandy loam, having sand 73.17 per cent, silt 15.2 per cent and clay 11.63 per cent. It was observed that the field capacity of soil was 26.81 per cent and permanent wilting point was 11.6 per cent. Thus, available moisture content was 15.18 per cent. The bulk density of soil was observed as 1.40 g/cm^3 with the porosity of 47.04 per cent. The basic infiltration rate was recorded as 6.27 cm/hr and hydraulic conductivity was 4.91 cm/hr. Thus, it can be concluded that this type of soil requires frequent irrigation.

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